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(74) Agents: **DONALD, Heather, June** et al.; Spoor and Fisher, PO Box 41312, 2024 Craighall (ZA).

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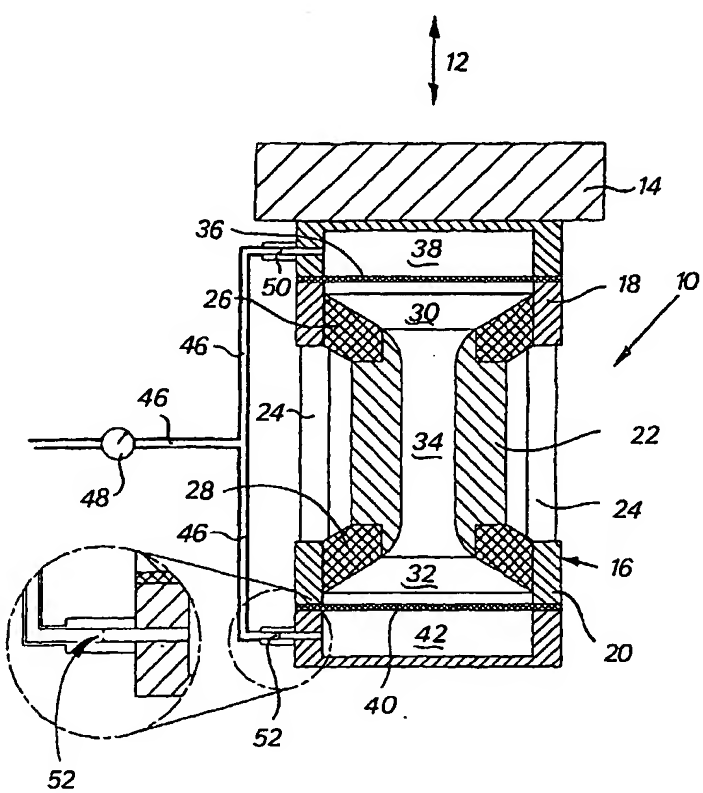
(54) Title: VIBRATION ISOLATOR



(57) Abstract: The invention provides a vibration isolator (10) for minimising the transfer of vibration forces from a vibrating body to an isolated body (14). The vibration isolator (10) includes a housing (16) which comprises housing components (18, 20 and 22) resiliently connected to one another to define a first reservoir (30), a second reservoir (32) and a port (34). The port (34) connects the first reservoir (30) to the second reservoir (32) and is displaceable relative to the first and second reservoirs so as to vary the volume of the reservoirs in response to relative motion between the vibrating body and the isolated body (14) along an axis of the housing. A fluid mass is contained within the first reservoir (30), the second reservoir (32) and the port (34), and the vibration isolator (10) includes two tuning diaphragms (36 and 40) operable on the fluid mass. The stiffness of the tuning diaphragms (36 and 40) is adjustable by varying the pressure within chambers (38 and 40) adjacent these diaphragms.

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Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4 811 919 A (JONES PETER J) 14 March 1989 (1989-03-14) column 7, line 23 - line 37; figure 3	1,16,28
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 4 416 445 A (COAD L DALE) 22 November 1983 (1983-11-22) abstract	1,16,28
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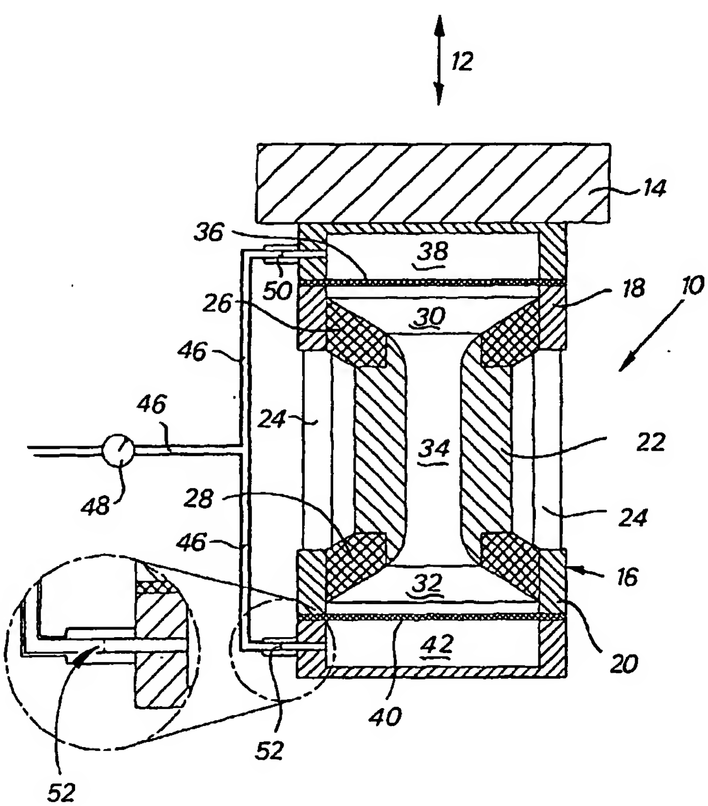
(54) Title: VIBRATION ISOLATOR



(57) Abstract: The invention provides a vibration isolator (10) for minimising the transfer of vibration forces from a vibrating body to an isolated body (14). The vibration isolator (10) includes a housing (16) which comprises housing components (18, 20 and 22) resiliently connected to one another to define a first reservoir (30), a second reservoir (32) and a port (34). The port (34) connects the first reservoir (30) to the second reservoir (32) and is displaceable relative to the first and second reservoirs so as to vary the volume of the reservoirs in response to relative motion between the vibrating body and the isolated body (14) along an axis of the housing. A fluid mass is contained within the first reservoir (30), the second reservoir (32) and the port (34), and the vibration isolator (10) includes two tuning diaphragms (36 and 40) operable on the fluid mass. The stiffness of the tuning diaphragms (36 and 40) is adjustable by varying the pressure within chambers (38 and 40) adjacent these diaphragms.

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VIBRATION ISOLATOR

BACKGROUND OF THE INVENTION

THIS invention relates to vibration isolators for minimising the transfer of vibration forces from a vibrating body to a body attached thereto. More specifically, the invention relates to an inertia-type vibration isolator having a mechanism for dynamically tuning the isolator within a range of excitation frequencies. The invention also relates to a method of tuning, and to a method of operating, a vibration isolator.

For purposes of this specification, the term "vibration isolator" will be used in respect of isolating or at least partially isolating a first body from vibrations in a second body to which the first body is connected. The invention is not directed at a vibration absorber mounted on a vibrating body to absorb or attenuate vibrations of the vibrating body.

The dynamic stiffness of conventional elastomeric or steel spring vibration isolators generally increases with increased frequency. This is undesirable because vibration isolators ideally should have a relatively high static stiffness for supporting an isolated mass and a relatively low dynamic stiffness for ensuring low transmission of dynamic forces.

A number of devices utilising hydraulic mass amplification are known. For example, US 4,236,607 discloses a spring-tuning mass vibration isolator which employs hydraulic fluid as an absorber mass, and which relies on displacement of the hydraulic fluid through a port between two reservoirs to generate amplified counter-inertial forces for cancelling vibration. The dynamic stiffness of this device is less than the static stiffness for a particular frequency band.

A disadvantage associated with vibration isolators of the type disclosed in US 4,236,607 is that they operate at a single frequency only and hence have a limited effective frequency band. Since the excitation frequency often is a function of environmental or operating conditions, for instance load, these vibration isolators cannot always cover the range of excitation frequencies encountered.

One way of increasing the effective frequency band is to decrease damping. However, there are physical limits on the amount of damping reduction that can be achieved in practice. Another way of increasing the effective frequency band is to tune the vibration isolator by adjusting the isolation frequency to achieve a greater suppression band as opposed to increasing the frequency band at a fixed isolation frequency. This can be achieved by determining the excitation frequency and adjusting a system parameter so that the isolation and excitation frequencies coincide.

Although the isolation frequency is known to be very sensitive to the port diameter, this parameter is relatively difficult to adjust in practice due to the incompressibility of the absorber fluid. A vibration isolation system in which isolators are tuned by varying the dimensions of the tuning passage is disclosed in US 5,788,029. This patent also discloses a tuning method involving the

application of magnetohydrodynamic force to the liquid within the tuning passage.

It is an object of the present invention to provide an alternative inertia-type vibration isolator which includes a mechanism for tuning the isolator.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a method of tuning a vibration isolator of the kind including:

a housing having spatially opposed reservoirs;

a port member movable relative to the housing and providing a port interconnecting the reservoirs in fluid flow relationship, the reservoirs and the port providing a closed volume; and

an incompressible fluid mass filling said closed volume,

in which a vibrating body is connected to one of the housing and the port member and an isolated body is connected to the other of the housing and the port member,

the method including rendering supporting of the incompressible fluid mass in the closed volume compliant, and adjusting the compliance.

"Compliant" and "compliance" are to be interpreted as the reciprocals of "stiff" and "stiffness" which are used in their technical sense, i.e. necessarily implying resilience or elasticity.

Expressed in another way, the method may include rendering supporting of the incompressible fluid mass in the closed volume finitely stiff and adjusting

the stiffness. The closed volume will generally be of fixed capacity. Thus, generally, the housing will be rigid and the port member will be rigid.

The method may include exposing the incompressible fluid mass in the closed volume to a resilient force, for example bounding a portion of the closed volume by means of a movable partition and subjecting the partition to pressure. In one arrangement, the method includes exposing the fluid mass in each of the respective reservoirs to such a resilient force. The respective resilient forces may be applied interdependently, preferably symmetrically.

The method may include providing a tuning chamber proximate each reservoir, and charging a compressible fluid into the tuning chambers, preferably from a common source of gas under pressure. Charging gas into the tuning chambers may be via one or more flow restrictors to enable a desired pressure nominally to be achieved within the tuning chambers and substantially to prevent transient pressure changes in the tuning chambers to be cancelled. Instead, charging the gas into the tuning chambers may be via valves under the control of a control arrangement.

Tuning the vibration isolator may be to a desired frequency, e.g. an isolation frequency which will generally be equal to the vibration frequency of the vibrating body, which will be referred to as the excitation frequency.

In accordance with a second aspect of the invention, there is provided a method of operating a vibration isolator, including carrying out the method of the first aspect continually or continuously to modulate adjustment in response to changes in the excitation frequency.

When the vibrating body is in the form of a pneumatic or hydraulic device or apparatus, such as a rock drill, the method may include effecting tuning in response to changes in the pneumatic or hydraulic pressure supply to the device or apparatus. The method may then include using the pneumatic or hydraulic pressure supply as a source of pressure for pressurizing the tuning chambers.

In accordance with a third aspect of the invention, there is provided a vibration isolator device including:

a housing having spatially opposed reservoirs;

a port member movable relative to the housing and providing a port or passage interconnecting the reservoirs in fluid flow relationship, the reservoirs and the port providing an enclosed volume; and

an adjustable tuning structure for use in rendering supporting of an incompressible fluid mass when contained in the enclosed volume compliant to a desired degree.

The adjustable tuning structure must be understood to be able to render supporting of an incompressible fluid mass when contained in the closed volume finitely stiff to a desired degree.

The vibration isolator device may be in the form of a vibration isolator containing an incompressible fluid filling the closed volume.

The closed volume may be symmetric.

The adjustable tuning structure may include a tuning chamber proximate each reservoir, a movable partition dividing each tuning chamber and the respective

reservoir, and a charging structure for charging a compressible fluid or gas into the respective tuning chambers at variable pressure. In one arrangement, the movable partition is a diaphragm. Typically, the charging structure is common to both tuning chambers to ensure equal pressures in the respective tuning chambers. The charging structure may include at least one orifice through which gas is charged, the orifice being adapted to allow flow of gas to achieve a desired nominal pressure in the tuning chambers and to prevent cancellation of transient pressure changes in the tuning chambers. Instead, the charging structure may include valves for controlling the pressure in the tuning chambers.

In accordance with a fourth aspect of the invention, there is provided an apparatus including a vibrating body which vibrates in use, an isolated body for holding or mounting the apparatus, and a vibration isolator in accordance with the invention interconnecting the vibrating body and the isolated body.

The apparatus may include a control arrangement for sensing an excitation frequency and for controlling the charging arrangement of the vibration isolator, in response to said excitation frequency, to tune the vibration isolator to an isolation frequency corresponding to said excitation frequency.

When the apparatus is in the form of a pneumatically or hydraulically driven apparatus, the charging system may be exposed to the pressure of the hydraulic or pneumatic supply automatically to charge the tuning chambers to a pressure commensurate in a predetermined relation to the hydraulic or pneumatic supply.

This invention is also applicable to a further class of devices or apparatuses which, in operation, do not vibrate in the normal sense of the word, but which undergo sudden movement of short duration, which may be a single movement, or mainly a single movement, which is periodic, for example a machine gun or the like.

More specifically, the invention provides a vibration isolator comprising:

a housing which includes housing components resiliently connected to one another to define a first reservoir, a second reservoir and a port, the port connecting the first reservoir to the second reservoir and being displaceable relative to the first and second reservoirs so as to vary the volume of the reservoirs in response to relative motion between a vibrating body and an isolated body along an axis of the housing;

a fluid mass contained within the first reservoir, the second reservoir and the port;

at least one tuning diaphragm operable on the fluid mass; and

adjustment means for adjusting the stiffness of the at least one tuning diaphragm.

In a preferred embodiment, a tuning diaphragm is operable on the fluid mass in each of the first and second reservoirs.

The tuning diaphragms may be formed from an elastomeric material, and may form a partition between a first chamber adjacent the first reservoir, and between a second chamber adjacent the second reservoir.

In one arrangement, the vibration isolator includes means for connecting the first chamber and the second chamber to a source of pressurised air. In this

embodiment, the vibration isolator may include a valve or a choke for controlling or limiting the flow of air into or out of the first chamber and the second chamber.

Conveniently, the vibration isolator includes a control system for automatically adjusting the air pressure within the first chamber and the second chamber, and hence the stiffness of the tuning diaphragms, in response to a change in the excitation frequency.

Alternatively, the vibration isolator may include means for manually adjusting the air pressure within the first and second chambers when the excitation frequency changes.

In yet another embodiment, the vibration isolator may be designed so that the isolation frequency coincides with the excitation frequency for all values of supply pressure within a given range.

Typically, the housing comprises a pair of outer housing components which partly define the first and second reservoirs, and an inner housing component which defines the port, the inner housing component being resiliently mounted to the outer housing components for reciprocal motion relative to the first and second reservoirs.

The resilient connection between the inner housing component and the outer housing components may comprise an elastomeric spring, a steel spring or a pneumatic spring.

Ideally, the fluid mass comprises a dense, incompressible fluid with a relatively high surface tension and a relatively low viscosity, for example liquid mercury. In this case, the rigid components of the housing may be formed from stainless steel or may be coated with a protective coating to resist the corrosive effect of mercury. Other, lower density liquids may also be used where increases in the dimensions of the vibration isolator are acceptable.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows, diagrammatically, a cross-sectional view of a vibration isolator according to the present invention;

Figure 2 is a graph illustrating a roll-off line fitted through the minimum transmissibility points on a set of transmissibility curves obtained by varying the diaphragm stiffness; and

Figure 3 is a graph illustrating the isolation frequency as a function of the supply pressure.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 of the drawings illustrates a vibration isolator 10 according to the present invention. The isolator 10 is designed for connection between a

vibrating body (not shown), oscillating along the line 12, and a body 14 to be isolated. The vibration isolator 10 includes a housing 16 composed of outer housing components 18 and 20 and an inner housing component 22.

In the illustrated embodiment, the housing components 18 and 20 are spaced from one another by rigid spacers 24, and the inner housing component 22 is resiliently connected to the outer housing components with elastomeric, primary springs 26 and 28. These springs serve to transfer loads and to form a seal between the inner housing component 22 and the outer housing components 18 and 20. It will be appreciated that the springs 26 and 28 need not be formed from an elastomeric material and that with suitable modifications the sealing function and the load-transfer function could be separated, in which case these springs could be steel springs or pneumatic springs.

The inner and outer housing components are seen in Figure 1 to define a first reservoir 30, a second reservoir 32 and a port 34 connecting the first reservoir to the second reservoir. The reservoirs 30 and 32 and the port 34 contain a fluid mass which preferably is a dense, incompressible liquid having a relatively high surface tension and a relatively low viscosity, for example liquid mercury.

A diaphragm 36 defines an outer limit to the reservoir 30 and separates this reservoir from an adjacent chamber 38. Similarly, a diaphragm 40 defines an outer limit to the reservoir 32 and separates this reservoir from an adjacent chamber 42. The chambers 40 and 42 are connected to a supply of pressurised air (not shown) via conduits 46 and a pressure control valve 48, and serve as air springs for the reservoirs 30 and 32, in use. A Choke in the form of an orifice 50 limits the flow rate of air into and out of the chamber 38, and a choke (which is

enlarged for clarity in Figure 1) in the form of an orifice 52 limits the flow rate of air into and out of the chamber 42.

In practice, the inner housing component 22 is connected to a vibrating body (not shown) and the outer housing component 18 is connected to an isolated body which is designated with the reference numeral 14 in Figure 1. It should be appreciated that this arrangement could be reversed so that the vibrating body is connected to the outer housing component 18 and the isolated body is connected to the inner housing component 22.

The application of vibrationary forces to the inner housing component 22 causes relative motion between this component and the outer housing components 18 and 20. The volumes of the reservoirs 30 and 32 are alternately increased and decreased as the port 34 reciprocates relative to these reservoirs, and this causes the liquid mass to be pumped back and forth through the port 34. Without the liquid mass, the isolated body 14 is simply suspended by the primary springs 26 and 28. However, the inertia of the liquid mass modifies the dynamic stiffness of the isolator 10 to be less than the static stiffness thereof over a particular frequency band.

The purpose of the diaphragms 36 and 40 is to allow for tuning of the vibration isolator 10 to the excitation frequency. This is achieved by modifying the continuity equation for the device which is represented as:

$$A_b y + \frac{1}{3} A_b (u - y) = \left[\frac{A_b d_b - A_o d_o}{3(d_b - d_o)} - A_a \right] (x - y) + (A_b - A_a) y + A_a x_B$$

where:

x_B	represents the displacement of the fluid in the port;
d_b	represents the diameter of the reservoir;
d_o	represents the diameter at the entrance to the port;
A_a	represents the area defined by the diameter of the port;
A_b	represents the area defined by the diameter of the reservoir;
A_o	represents the area defined by the diameter at the entrance to the port;
x	represents the displacement of the port;
y	represents the displacement of the reservoir; and
u	represents the displacement at the centre of the diaphragm.

In essence, the stiffness of the diaphragms 36 and 40 will control the amount of fluid displaced, and the dynamic characteristics of displacement such as velocity and acceleration, through the port 34, which in turn will vary the isolation frequency. In the illustrated embodiment, the stiffness of the diaphragms 36 and 40 is a function of the air pressure within the chambers 38 and 42, and the stiffness of the elastomeric material forming the diaphragms. If a large tuning band and low damping is to be achieved, the diaphragm stiffness must be minimised.

The orifices 50 and 52 allow air into or out of the chambers 38 and 42 at low frequencies and minimise this airflow at high frequencies. This allows for tuning of the isolator 10 since the pressure changes within each chamber 38 and 42 due to the flexing of the diaphragms 36 and 40 at a given excitation frequency will occur too quickly to allow substantial airflow across the chokes, but the average pressure in the chambers 38 and 42 will eventually equal the average pressure in the conduit 46.

If a small orifice diameter is selected, the tuning rate will be compromised. Accordingly, applications requiring rapid tuning will include a more sophisticated arrangement, such as a solenoid valve for sealing the chambers 38 and 42 from the conduit 46 during steady state operation and allowing relatively high flow rates across the valve during pressure adjustments.

The tuning may be effected automatically by a control system which determines the excitation frequency and automatically adjusts the stiffness of the diaphragms 36 and 40 by increasing or decreasing the air pressure within the chambers 38 and 42, thereby to ensure that the isolation frequency and the excitation frequency coincide. This adjustment could also be effected manually.

In experimental tests, a vibration isolator according to the present invention with a liquid mass of water and a glycol additive was connected to a Zonic hydraulic actuator and loaded with masses in 10kg increments. The acceleration was measured on the actuator and on the isolated mass with 100mV/g PCB ICP accelerometers. A 5Hz bandpass filter was applied to the input and output signals to ensure single frequency transmissibility measurements, and the input accelerometer provided feedback to ensure a constant acceleration input from 10Hz to 70Hz. The tests produced transmissibility curves for which the lowest recorded coherence was 0.98.

Figure 2 illustrates the transmissibility curve set for a 47.5kg isolated mass. The points of minimum transmissibility are connected with a linear curve fit, as shown. The broken line represents a corresponding curve for a conventional vibration isolator. The slope of the curves for the various values of isolated mass used in the tests are summarised in the Table below:

Roll-off slopes for tested isolated masses

Mass [kg]	Roll-off slope [dB/decade]
17.5	-94.7
27.5	-95.9
37.5	-93.0
47.5	-89.3

For the four isolated masses used, the diaphragm stiffness was found to be the same and consistently increasing with pressure.

Figure 3 shows the isolation frequency as a function of supply pressure. This graph shows that the isolation frequency could be changed by 12 Hz. The relationship between pressure and isolation frequency is given by:

$$f_i = -0.280p_s^2 + 3.787p_s + 22.473$$

where:

p_s represents the supply pressure in bars; and

f_i represents the isolation frequency.

The roots of this equation can be used to tune the vibration isolator in a simple arrangement where the excitation frequency is measured and the supply pressure is adjusted to find the closest isolation frequency.

The experimental set-up achieved roll-off values more than twice that of a conventional isolator over a 12 Hz frequency band.

It will be understood that the isolator 10 may be applied in a wide range of different applications. For example, the vibration isolator may be used on vibrating machinery, such as vibrating mixers and separators, vibration transport and processing machines, or vibration crushers; rotating machinery including turbocompressors and turbopumps; reciprocating machinery; pneumatic hand tools; and impact machinery such as compactors. The vibration isolator may also be used in devices undergoing a single, or mainly a single, sudden jerk which is periodic such as in a machine gun.

A major advantage of the vibration isolator 10 is that it is effective in isolating vibration over a relatively broad excitation frequency band by the continual, dynamic tuning of the device to an isolation frequency corresponding to a varying excitation frequency. It will also be appreciated that the static deflection is constant regardless of the pressure within the chambers 38 and 42. Furthermore, the isolator 10 can achieve lower transmissibility than a conventional isolator over a limited frequency band. It will also be understood that the vibration isolator according to the present invention can be manufactured as a relatively small, robust and lightweight unit which is easy to handle.

CLAIMS

1. A method of tuning a vibration isolator of the kind including:

   a housing having spatially opposed reservoirs;

   a port member movable relative to the housing and providing a port interconnecting the reservoirs in fluid flow relationship, the reservoirs and the port providing a closed volume; and

   an incompressible fluid mass filling said closed volume,

   in which a vibrating body is connected to one of the housing and the port member and an isolated body is connected to the other of the housing and the port member,

   the method including the steps of:

   rendering supporting of the incompressible fluid mass in the closed volume compliant; and

   adjusting the compliance.

2. A method according to claim 1, wherein the incompressible fluid mass in the closed volume is exposed to a resilient force.

3. A method according to claim 2, including exposing the fluid mass in each of the respective reservoirs to a resilient force.

4. A method according to claim 3, wherein the respective resilient forces are applied interdependently.

5. A method according to claim 4, wherein the respective resilient forces are applied symmetrically.

6. A method according to any one of claims 2 to 5, wherein exposing the incompressible fluid mass to the resilient force or forces includes bounding a portion of the closed volume by means of at least one movable partition and subjecting the at least one partition to pressure.

7. A method according to any one of the preceding claims, including providing a tuning chamber proximate each reservoir, and charging a compressible fluid into the tuning chambers.

8. A method according to claim 7, wherein the compressible fluid is charged into the tuning chambers from a common source of gas under pressure.

9. A method according to claim 8, wherein the gas is charged into the tuning chambers through one or more flow restrictors which are arranged to enable a desired pressure nominally to be achieved within the tuning chambers, and substantially to prevent cancellation of transient pressure changes in the tuning chambers.

10. A method according to claim 8, wherein the gas is charged into the tuning chambers through valves controlled by a control arrangement.

11. A method according to any one of the preceding claims, wherein the vibration isolator is tuned to an isolation frequency.

12. A method according to claim 11, wherein the vibration isolator is tuned to the excitation frequency of the vibrating body.

13. A method according to any one of the preceding claims, wherein the vibrating body is a pneumatic or hydraulic device or apparatus, and the method includes effecting tuning in response to changes in the pneumatic or hydraulic pressure supply to the device or apparatus.

14. A method according to claim 13, including using the pneumatic or hydraulic pressure supply as a source of pressure for pressurizing the tuning chambers.

15. A method of operating a vibration isolator including carrying out the method according to any one of the preceding claims continually or continuously to modulate adjustment in response to changes in the excitation frequency.

16. A vibration isolator device including:

a housing having spatially opposed reservoirs;

a port member movable relative to the housing and providing a port interconnecting the reservoirs in fluid flow relationship, the reservoirs and the port providing an enclosed volume; and

an adjustable tuning structure for use in rendering supporting of an incompressible fluid mass contained in the enclosed volume compliant to a desired degree.

17. A device according to claim 16, containing an incompressible fluid within the closed volume.

18. A device according to either claim 16 or claim 17, wherein the closed volume is symmetric.

19. A device according to any one of claims 16 to 18, wherein the adjustable tuning structure includes a tuning chamber proximate each reservoir, a movable partition dividing each tuning chamber and the respective reservoir, and a charging structure for charging a compressible fluid into the respective tuning chambers at variable pressure.

20. A device according to claim 19, wherein the movable partition is a diaphragm.

21. A device according to either claim 19 or claim 20, wherein the charging structure is common to both tuning chambers to ensure equal pressures in the respective tuning chambers.

22. A device according to any one of claims 19 to 21, wherein the charging structure includes at least one orifice through which gas is charged, the orifice being adapted to allow flow of gas to achieve a desired nominal pressure in the tuning chambers, and to prevent cancellation of transient pressure changes in the tuning chambers.

23. A device according to any one of claims 19 to 21, wherein the charging structure includes valves for controlling the pressure in the tuning chambers.

24. An apparatus including a vibrating body which vibrates in use, an isolated body for holding or mounting the apparatus, and a vibration isolator device according to any one of claims 16 to 23 interconnecting the vibrating body and the isolated body.

25. An apparatus according to claim 24, including a control arrangement for sensing an excitation frequency and for controlling the charging arrangement of the vibration isolator device, in response to said excitation frequency, to tune the vibration isolator to an isolation frequency corresponding to said excitation frequency.

26. An apparatus according to either claim 24 or claim 25, wherein the apparatus is in the form of a pneumatically or hydraulically driven apparatus.

27. An apparatus according to claim 26, wherein the charging system is exposed to the pressure of a hydraulic or pneumatic supply automatically to charge the tuning chambers to a pressure commensurate in a predetermined relation to the hydraulic or pneumatic supply.

28. A vibration isolator comprising:

a housing which includes housing components resiliently connected to one another to define a first reservoir, a second reservoir and a port, the port connecting the first reservoir to the second reservoir and being displaceable relative to the first and second reservoirs so as to vary the volume of the reservoirs in response to

relative motion between a vibrating body and an isolated body along an axis of the housing;

a fluid mass contained within the first reservoir, the second reservoir and the port;

at least one tuning diaphragm operable on the fluid mass; and

adjustment means for adjusting the stiffness of the at least one tuning diaphragm.

29. A vibration isolator according to claim 28, wherein a tuning diaphragm is operable on the fluid mass in each of the first and second reservoirs.

30. A vibration isolator according to claim 29, wherein the tuning diaphragms are formed from an elastomeric material, and form a partition between a first chamber adjacent the first reservoir, and between a second chamber adjacent the second reservoir.

31. A vibration isolator according to claim 30, including means for connecting the first chamber and the second chamber to a source of pressurised air.

32. A vibration isolator according to claim 31, including a valve or a choke for controlling or limiting the flow of air into or out of the first chamber and the second chamber.

33. A vibration isolator according to either claim 31 or claim 32, including a control system for automatically adjusting the air pressure within the first chamber and the second chamber, and hence the stiffness of the

tuning diaphragms, in response to a change in the excitation frequency.

34. A vibration isolator according to either claim 31 or claim 32, including means for manually adjusting the air pressure within the first and second chambers when the excitation frequency changes.

35. A vibration isolator according to any one of claims 31 to 34, wherein the vibration isolator is designed so that the isolation frequency coincides with the excitation frequency for all values of supply pressure within a given range.

36. A vibration isolator according to any one of claims 28 to 35, wherein the housing comprises a pair of outer housing components which partly define the first and second reservoirs, and an inner housing component which defines the port, the inner housing component being resiliently mounted to the outer housing components for reciprocal motion relative to the first and second reservoirs.

37. A vibration isolator according to claim 36, wherein the resilient connection between the inner housing component and the outer housing components comprises an elastomeric spring, a steel spring or a pneumatic spring.

38. A vibration isolator according to any one of claims 28 to 37, wherein the fluid mass comprises a dense, incompressible fluid with a relatively high surface tension and a relatively low viscosity.

39. A vibration isolator according to claim 38, wherein the fluid mass comprises liquid mercury.

40. A vibration isolator according to claim 39, wherein the rigid components of the housing are formed from stainless steel or are coated with a protective coating to resist the corrosive effect of mercury.

Fig 1

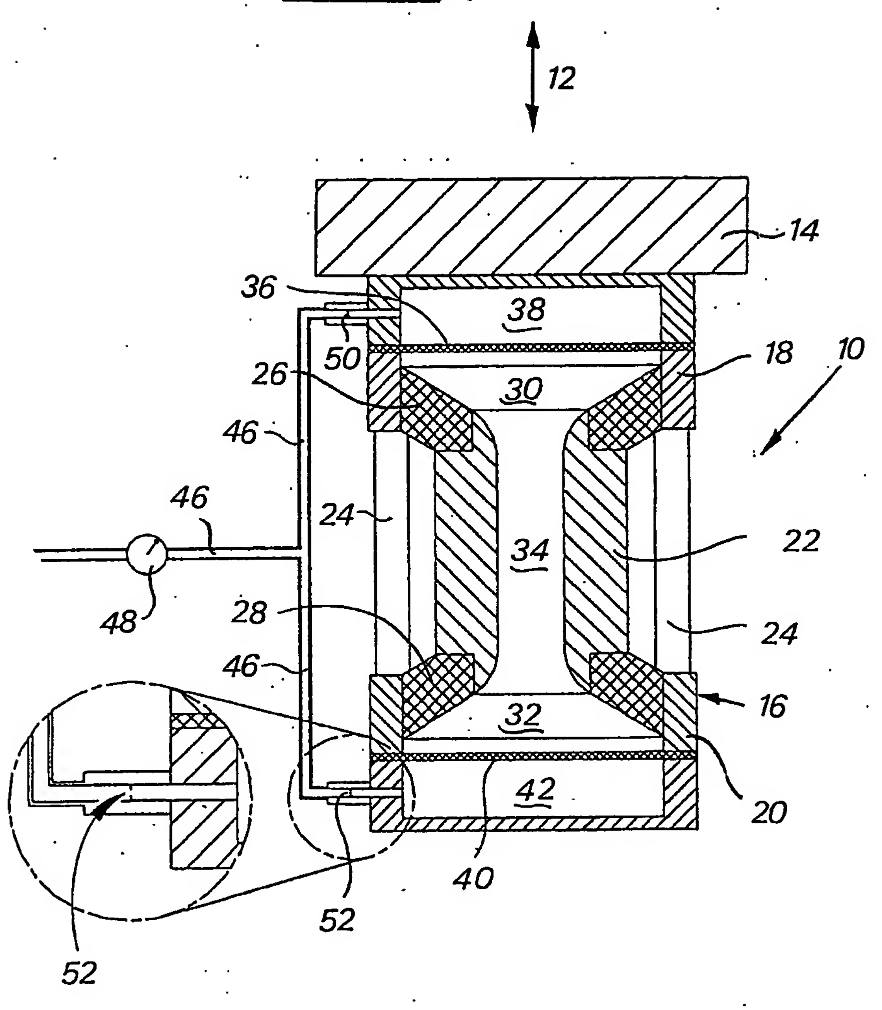
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FIG 2

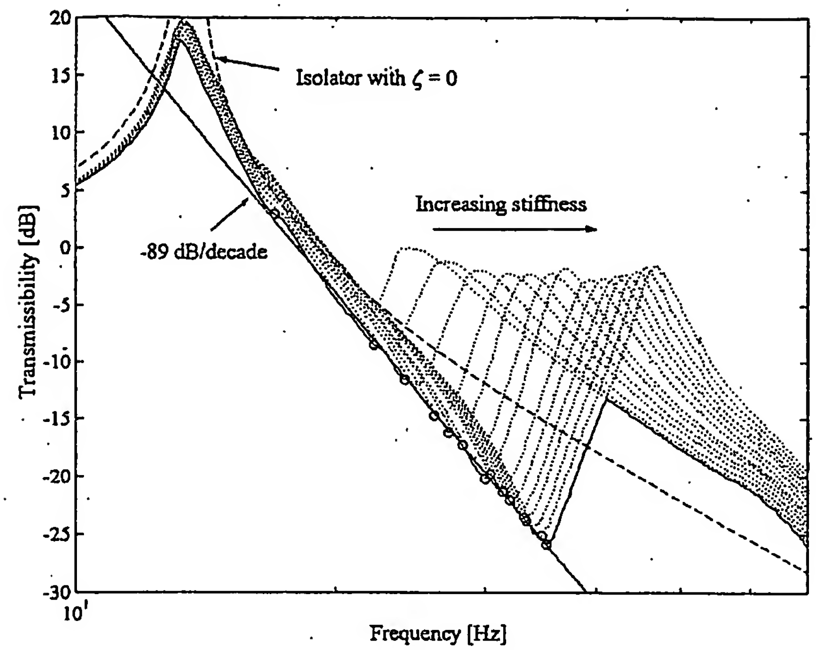
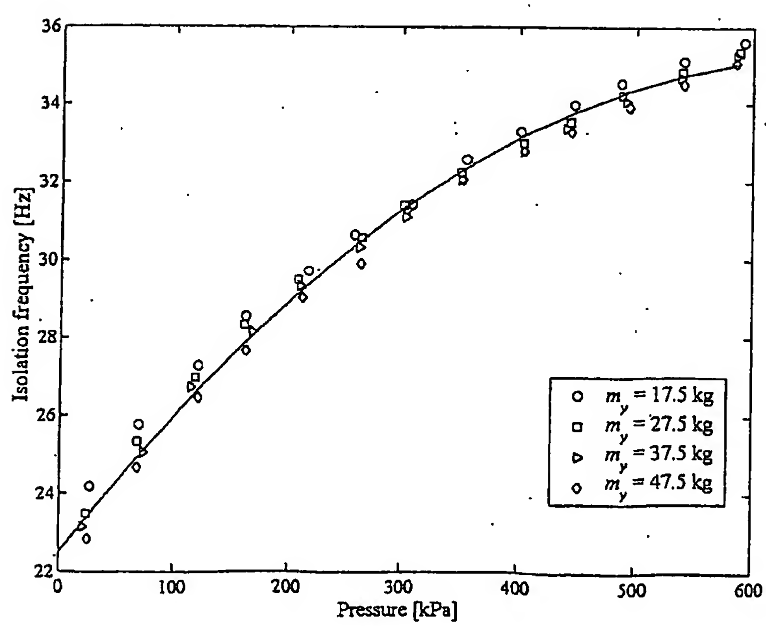

Isolator with ζ = 0
Increasing stiffness
-89 dB/decade
Transmissibility [dB]
Frequency [Hz]
20
15
10
5
0
-5
-10
-15
-20
-25
-30
10^1

FIG 3


Isolation frequency [Hz]
Pressure [kPa]
m_y = 17.5 kg
m_y = 27.5 kg
m_y = 37.5 kg
m_y = 47.5 kg
36
34
32
30
28
26
24
22
0
100
200
300
400
500
600

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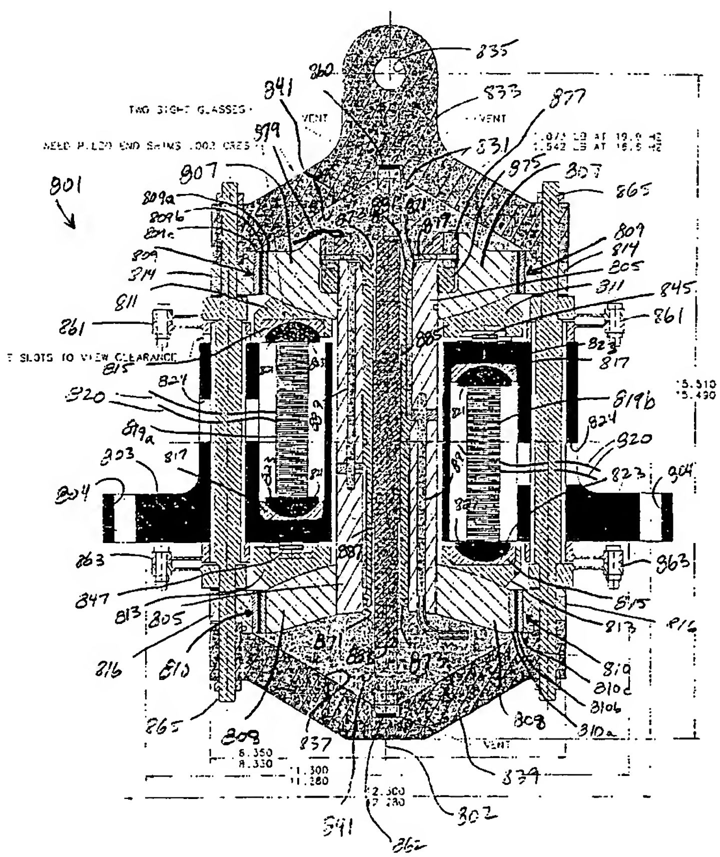
(54) Titre : PROCEDE ET DISPOSITIF D'ISOLATION AMELIOREE CONTRE LES VIBRATIONS

(54) Title: METHOD AND APPARATUS FOR IMPROVED VIBRATION ISOLATION



(57) Abrégé/Abstract:
A tunable vibration isolator (451, 551, 651, 681, 691, 721, 801, 901, 973) with active tuning elements (473, 475, 573, 673, 675, 689, 705, 707, 745, 747, 747, 819a, 819b) having a housing which defines fluid chambers. A piston (455, 555, 655, 695, 725,

(57) Abrégé(suite)/Abstract(continued):
805, 970) is disposed within the housing. A vibration isolation fluid is disposed within the fluid chambers. A passage (463, 563, 663, 735, 881, 904) having a predetermined diameter extends through the piston to permit the vibration isolation fluid to flow from one fluid chamber to the other. The tunable vibration isolator may employ either a solid tuning mass approach or a liquid tuning mass approach. In either case, active tuning elements, or actuators, are disposed in the fluid chambers to selectively tune the vibration isolator.

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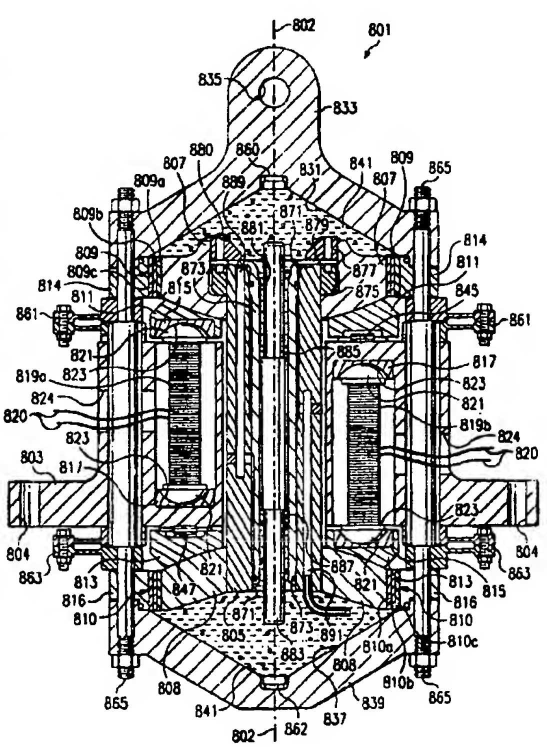
(54) Title: METHOD AND APPARATUS FOR IMPROVED VIBRATION ISOLATION



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